Girard (A. C.) Colonel J. S. Billings

Compliments of the Author.

THE LATEST EXPERIMENTS

ON THE

EFFECT OF SMALL CALIBRE RIFLES.

BY MAJOR ALFRED C. GIRARD,

Surgeon U. S. Army.

Repr. fr

~~Rev.~~ Tr. Aso. Mil.
Surg., U.S. St. Louis

1894. IV: 382-400

Buxton & Skinner

THE LATEST EXPERIMENTS ON THE EFFECT OF SMALL CALIBRE RIFLES.

A Resume of Experiments of Prof. Kocher of Berne, the German Commission of Berlin, and Prof. Demosthene of Bucharest.

By Major Alfred C. Girard,
Surgeon U. S. Army.

It has been my desire to present before this meeting of the Association of the Military Surgeons of the United States a sequel to the report made by me at the Chicago meeting on the comparative effect of large and small calibre guns, and I regret very much not being able to do this in person and that I can only at this time submit in an abbreviated form the result of my inquiries on the subject while abroad. The reason is, that while I had repeatedly examined the specimens of Prof. Kocher's experiments and had his results explained to me by him, I had to await the delivery of his paper on the subject at the Congress in Rome, where also I heard the report of the German Commission and of Prof. Demosthene of Bucharest.

The short time available between the sessions of the Congress and the mailing time of my report in order to reach your meeting, and the inconvenience of doing literary work while traveling, prevent my making a full report to your meeting.

Experiments of Prof. Th. Kocher, at Berne.

Introduction.

The experiments were made with various weapons and projectiles at reduced distances. Formerly from 8 to 30 meters, of late years the distance has been uniformly 10 meters.

The weapon used with the older experiments was the Vetterli, cal. 10, 4, in the later ones the Schmidt, model 1889, cal. 7, 5. Some experiments were made with a Schmidt, cal. 6. For the greater velocity the ordinary charge of the gun was used, giving in the Vetterli an initial velocity of 425 m., in the Schmidt, 600. The shots of 425, resp. 600 velocity are therefore to be considered as short range ones with the ordinary charge. In order to imitate greater distances the charges were reduced.

Methods of Experiments.

The purpose of these experiments was a two-fold one: First to investigate in a general way the effects of the projectiles and to reduce

them to specific laws, and second, to ascertain the effects on the human and animal body.

For the first purpose the firing was made on glass, rosin, metal, stone, clay and soap plates; also on tin cans with various contents, and on dried bones, etc. In the experiments for the second purpose fresh bones, animal flesh and human cadavers were employed.

Results.

The results are also divided into two categories: Those relating generally to the effect of gun projectiles and those relating to animal tissues.

The following are the main results of the theoretical experiments:

1. We find in great velocities (consequently at short range) a more or less pronounced lateral effect—a transmission of the live energy—even in dry, brittle substances, without rotation or deformity. This effect is commonly called *explosive*. The proof that neither rotation nor deformity were instrumental in these explosive effects is furnished by control-experiments with round bullets, without rotation and with projectiles not subject to deformation (steel), in which the explosive effect is very pronounced. (See Fig. 1-6, glass plates with explosive effect.) This centrifugal transmission of energy is well illustrated by the experiments with tin cans filled with marbles, where the marbles made impression on the tin in every direction, even that of entrance and on themselves. (See Fig. 7.)

In the experiments on plates we find this lateral transmission of energy radiating from the entrance opening perpendicularly to the diameter, showing a greater defect at the exit. (See Fig. 8.)

We find a much larger channel than the diameter of the projectile, no matter what the deformity or lack of deformity may be, when delivered with great velocity.

2. In reduced velocity (practically greater distance), there is a zone, in which we find smooth perforations with very little lateral effect. In glass plates this zone exists for a velocity of 250-400 m. (corresponding with full charge to a distance of 1100-400 m.) In dry bones this zone extends much further, for even at short range we obtain smooth perforations without explosive effect. Likewise one of the preparations, a dry diaphysis of femur, shows with a velocity of 750 m. (increased charge) a simple perforation without fracture.

3. In still more reduced velocity, corresponding to increased distance (in the experiments of glass plates, velocity of 250 m. or distance of 1100 m. with full charge), the live energy is not sufficient any more for a smooth perforation, and lateral effects make their appearance which greatly differ from the explosive effect and rather

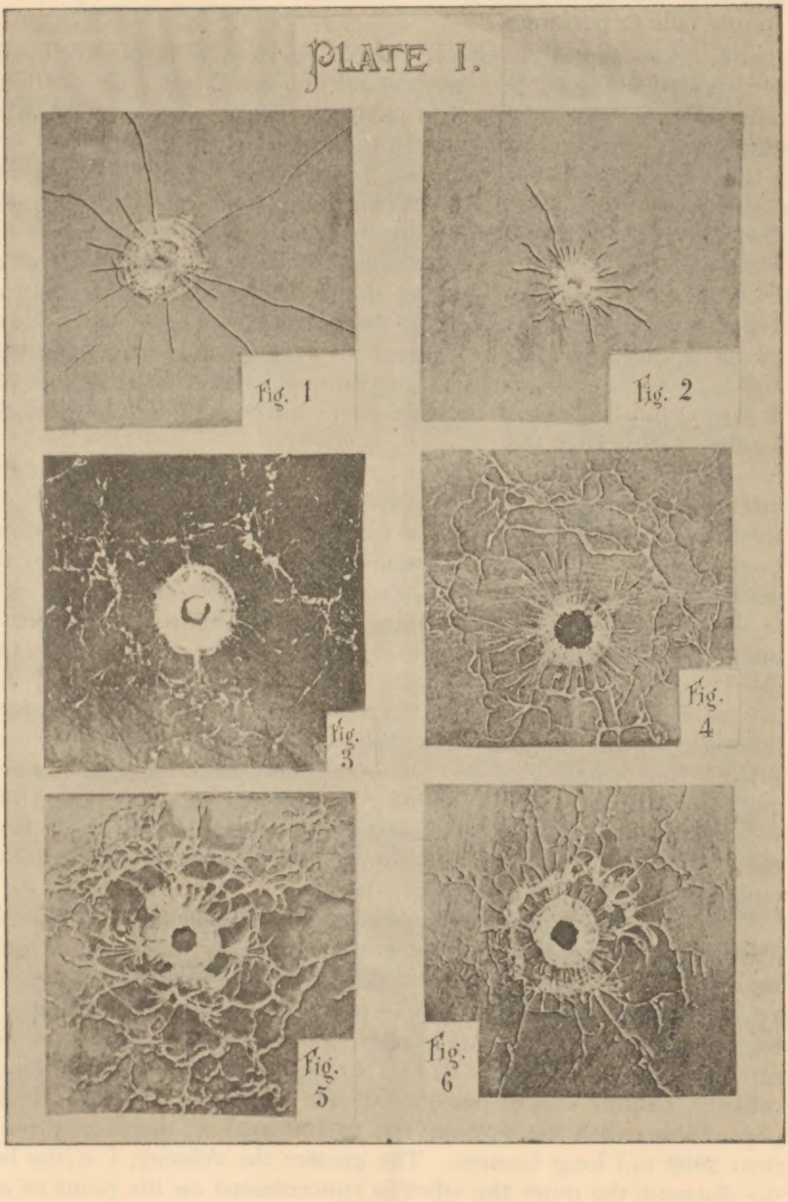
PLATE I.
Fig. 1
Fig. 2
Fig. 3
Fig. 4
Fig. 5
Fig. 6

resemble a blow with a blunt instrument (both radial and concentric cracks in the glass plates). In substances not brittle the projectile simply fails to perforate.

4. The explosive effect, *ceteris paribus*, is increased by the presence of fluids in the experimental bodies. Thus a tin can filled with water is torn to pieces by a shot with high velocity, while an empty can shows a simple perforation. The same obtained with a tin can filled with moist cotton, compared with one filled with dry cotton (see Figs. 9, 10, 11, 12). With reduced velocity, i. e., increased distance (velocity from 250 m. downwards, i. e., 1100 m. distance upwards), we find a simple perforation, even in a can filled with water. In semi-solid bodies we observe simple perforations under reduced velocity; with increased velocity the lateral effect (explosive) makes its appearance and increases progressively, in soap commencing with 100 m. (See Figs. 13 and 14.) The explosive effect is remarkable in large lumps of clay, even with steel projectiles, not subject to deformity. (See Fig. 15.)

5. The following results were shown in the effect on the animal or human body. (a) The soft tissues exhibit a decided explosive effect. In the liver, e. g., we find pulpification of the tissue even at a velocity of 300 m. (distance of 700 m.) At short range the destruction is great. Muscular tissue suffers less destruction, even at short range, with non-deforming projectiles, more with deformed ones. Reduced velocity produces simple perforations. (See Fig. 16.) (b) The following are the results in the skull: When empty and dry we never find explosive action, even at short range—the perforations are always smooth. (See Figs. 17 and 18.) When, however, filled with a semi-fluid mass (brain or potato pulp), it already shows explosive effects with a velocity of 250-300 (distance 700-1100), very pronounced in shots at close range (velocity of 660 m.). With reduced velocity we again find simple perforations, or the projectile remains in the bone. (See Figs. 19, 20.)

(c) In the extremities we have to distinguish between the diaphysis and the epiphysis. In moist epiphyses at much reduced velocity the projectile is arrested (see Fig. 21); in somewhat higher velocity (medium distance) simple perforations (see Fig. 22), and in high velocity (close range) greater defects, with fracture and disruption (see Figs. 23 and 24). Dry epiphyses, even with highest velocity, exhibit simple perforation (see Fig. 25). The moist diaphyses show with low velocity (up to 150 m., i. e., distance of more than 2000 m.) long fissures. The greater the velocity, i. e., the less the distance, the more the effect is concentrated on the point of entrance, the perforation combining with splintering, the effect in medium distances (velocity of 300 m., distance of 700 m.) exhibiting

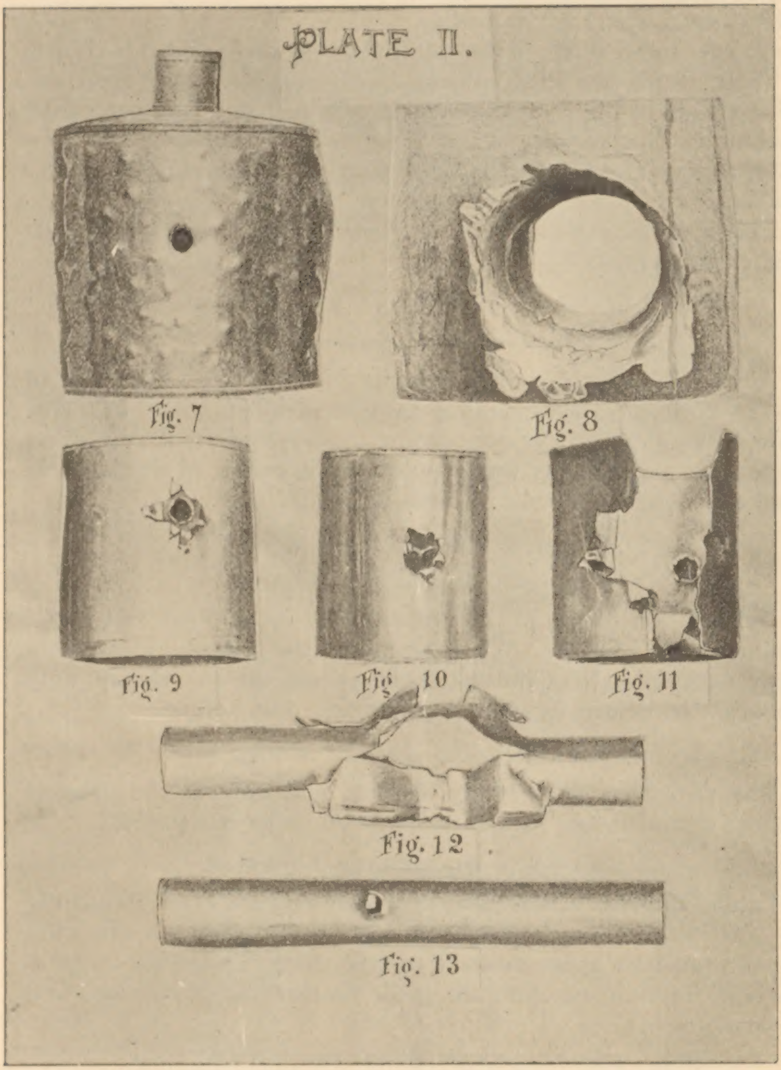
PLATE II.
Fig. 7
Fig. 8
Fig. 9
Fig. 10
Fig. 11
Fig. 12
Fig. 13

a smaller number of relatively large splinters, while in higher velocity 600 m.) we find complete comminution at the point of impact. (See Figs. 25—30.) In dry diaphyses we notice occasionally simple perforations even with high velocities.

(d) As to the effect of the material of the projectile, it is shown, that those which are least subject to deformation cause great explosive effects at high velocity (steel). Of course a number of the preparations show a very decided explosive effect with soft projectiles, as they are flattened in impact and have, therefore, a greater diameter.

This is about the substance of Prof. Kocher's view, and results of his experiments.

Experiments of Von Koler and Schjerning.

Methods of Experiments.

Always full charge (initial velocity of 640 m.) on distances of from 25–2000 m. corresponding to velocities of about 600–170; calibre 7, 9. The proper proportion of moisture in the cadavers used for the experiments was supplied by injection of fluids. The wound channels were filled with casts of fused Wood's metal.

(a) *On the Projectiles.*

1. Effect on the projectiles.

Deformation of the projectiles was greatest at short range and continued up to 1600 m. At greater ranges the projectiles were only slightly flattened. No deformation by impact on soft tissues, only on bones. In deformation the injuries are more severe.

2. Perforation and arrest in the body.

The projectiles were rarely arrested and only at the greatest distance; at times some part of the jacketed bullet is arrested.

3. Lateral impact and rotation.

Lateral impact causes greater destruction. This frequently takes place in the body owing to unequal resistance; and when the projectile retains a great amount of live energy it acquires a pendulum-like motion, resulting in great destruction of muscles and soft parts.

4. The temperature of projectiles.

By filling the jacket with a metallic compound, subject to fusion at a temperature of from 65-197 deg. C., it was proven that the projectile is only heated above 65 deg. when a number of consecutive shots are rapidly fired from the same gun. (In 100 shots in $2\frac{1}{2}$ minutes increase of temperature to 334 deg.) The projectile is

PLATE III.

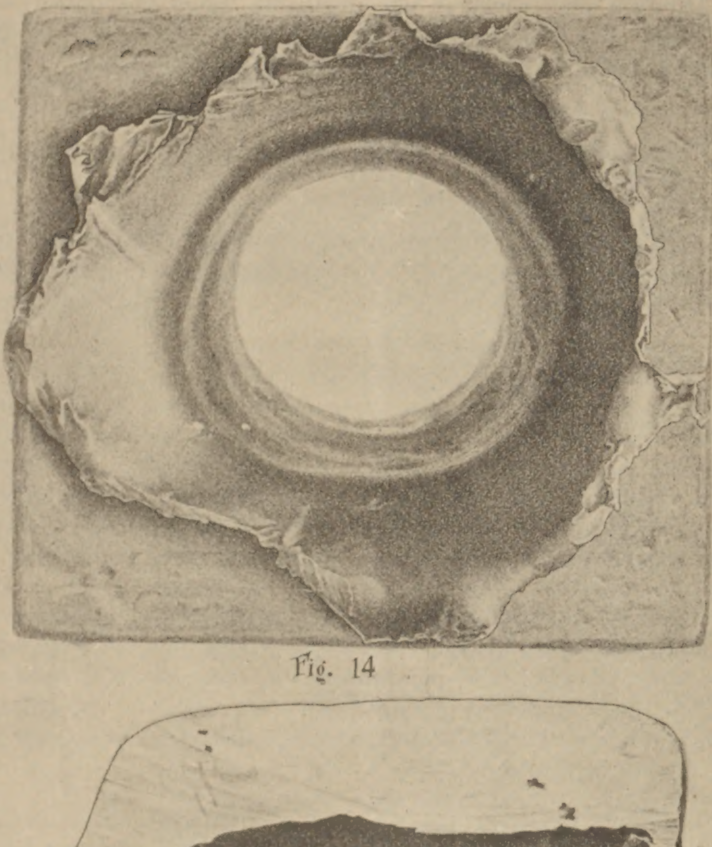

Fig. 14

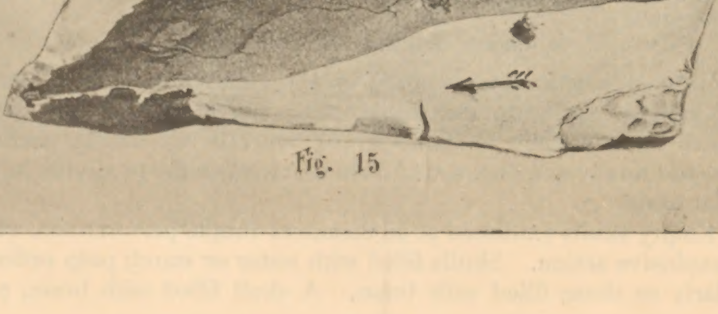

Fig. 15

heated to not more than 65-95 deg. C. in its passage through the human or animal body.

(b) *Effects of Projectiles.*

Division into zones is not justifiable, since the transition of the various effects is a gradual one, and the resistance of the different parts of the body and tissues alter it in every instance.

WOUNDS OF ENTRANCE OF THE SKIN.

Greater at short ranges, mostly smooth, largest in lateral impact.

WOUNDS OF EXIT OF THE SKIN.

Greater than the corresponding wound of entrance and more irregular. At close ranges they are very large, when a bone adjacent to the skin has been comminuted.

WOUNDS OF SOFT PARTS.

In muscles, smooth, straight wound channels, at close ranges somewhat larger, or at least as large as the calibre; at great ranges smaller. Greater destruction occurs only when the projectile meets resistance, is turned or strikes with lateral impact. The smaller blood vessels are torn, the larger ones seldom hit. When they are struck the injury to the intima is greatest. Complete division of larger vessels only at close range. In the heart we find simple perforations in systole, extensive destruction in diastole.

The lungs exhibit a narrow wound channel, the walls of which are infiltrated with blood. Result generally favorable, generally with pneumothorax; in 57 per cent. of the cases observed hemoptoe.

The liver is always greatly destroyed, extensive pulpification at close ranges. Explosive action evident yet at a distance of 2000 m. (velocity of 170 m.)

The spleen suffers in the same manner.

Stomach, intestinal tube, bladder: In penetrating abdominal wounds on an average 3, maximum 8 perforations, size and form of intestinal wounds vary. (Cases of such injuries among the living always fatal.)

GUNSHOT WOUNDS OF THE SKULL.

Explosive action (transmitted by the substance of the brain) at close ranges, generally decreasing with increased distance. At a distance of 1600-2000 m. (velocity of 200-170 m.) simple perforations; and finally at a distance of 2700 m. arrest of the projectile in the cranial cavity.

Empty skulls exhibited at all distances simple perforations, without explosive action. Skulls filled with water or starch pulp suffered similarly to those filled with brain. A skull filled with brain, per-

PLATE IV.

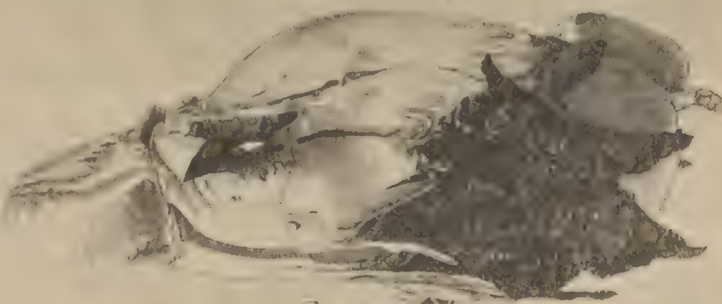

Fig. 16

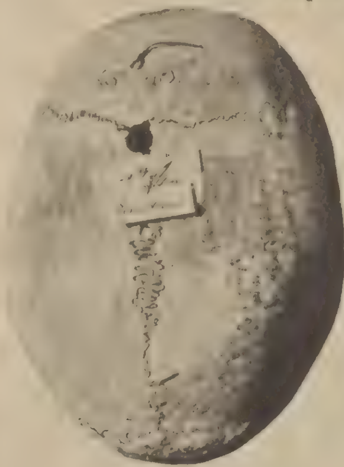

Fig. 17

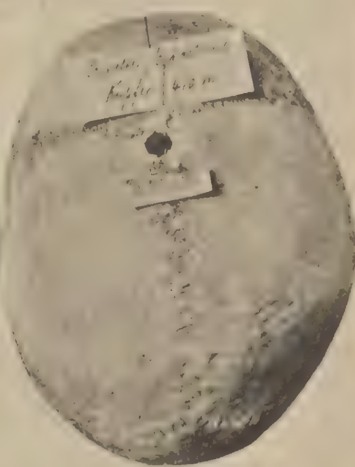

Fig. 18

forated with reduced charge, is said to have exhibited a simple perforation with a velocity of 300 m. corresponding to a distance of 700 m.

The brain is extensively destroyed in shots at close range; at longer ranges the wound channel is narrow.

EFFECT ON BONES.

At a distance of 100 m. (566 m. velocity) the diaphyses are comminuted into small fragments, the epiphyses likewise, sometimes with some cohesion by means of the periosteum.

The same results at a distance of 200 m. (500 m. velocity), with less destruction of the soft parts.

At 600 m. distance (319 m. velocity) the diaphyses were splintered, epiphyses sometimes simply perforated. Destruction of soft parts less severe.

At a distance of 800 m. (284 velocity) the epiphyses showed more simple perforations. At a distance of 1000 m. (260 m. velocity) diaphyses fractured in larger fragments; epiphyses, perforations. At 1200 m. distance (240 m. velocity) diaphyses still fissured, but less severely. Injury more severe at exit.

At a distance of 1600 m. (200 m. velocity) fracture of diaphyses, fragments held more together by the periosteum.

At 2000 m. (170 velocity) the diaphyses are still fissured, but the fragments remain in place, the periosteum having suffered but small lesion, although at times fragments are detached.

Thus far the report of the German Commission at the Congress.

I will now give a resume of an address made by Prof. Demosthene of Bucharest at the Congress. A full report of his experiments will be made later.

He stated that the weapon he used was a 6.5 Mannlicher and claimed to be the first who had made experiments with full charges at actual distances since the introduction of small calibre rifles. A preliminary report of his had appeared in the "Semaine Medicale" of 1893. The distances fired at were from 5 m. to 1400. He finds that the effects of the jacketed small calibre projectile are much more destructive than had been generally believed; that all bones were fractured, not only perforated, at all distances; that neither the skull nor the diaphysis of the long bone presented simple perforations; that the bullet causes severe hemorrhages, and on striking bones may be so shattered as to send sharp particles into the adjoining tissues; and that for these reasons, as well as for the increased range, the small calibre rifle is more destructive than the older arms with leaden bullets.

I have not yet been able to obtain the full report in printed

PLATE V.

Fig. 19

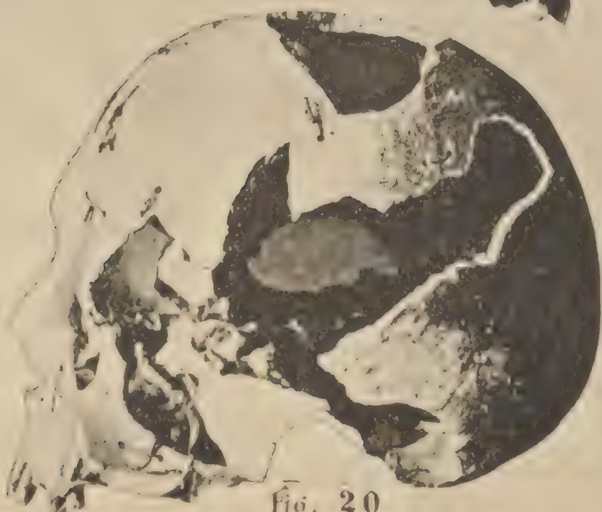

Fig. 20

form published by Prof. Demosthene, but will embody a review of it in the paper I hope to prepare on my return.

I will conclude with a short comparison of the results attained by Kocher at reduced distances and with generally reduced charges, and those of the German Commission.

The Germans used full charges at actual distances, while Kocher employed full charges only for the great velocities, always at reduced distances of 10 m., while in all other experiments he reduced the charge in the usual manner. Thus his series exceeds the distances at which the Germans were experimenting; being able to observe effects at a velocity of less than 170 m. or actual distance of over 2000 m. at which distance it was practically impossible for the Germans to obtain results, while the range is still important in actual warfare.

(In reporting on the German experiments, which give only the distances, I have approximately computed the velocities for easier comparison with Kocher's experiments.)

Although Koler and Schjerning claim a difference in the effect of reduced charges, it is not sufficiently great to vitiate the value of Kocher's experiments. It is possible that the more severe effects generally obtained by the Germans are due to an impact not absolutely perpendicular, thus not only causing a lateral transmission of energy, but a real lateral impact. This may be produced during the long flight of the bullet, which is naturally easily affected owing to its length by unequal atmospheric currents, by possible unequal filling or inequality of rifling at the muzzle, so minute as not observable with the eye, but sufficiently to lead to a more or less pronounced tilting. The Germans observe no tendency to deformation of the bullet on striking soft parts, such as liver; still it exists, as is well shown by Kocher's experiments on livers, muscle and water, with soft projectiles, and will practically come into play in case of weakening or injury to the jacket.

An arrest of the projectile occurs frequently according to Kocher in velocities below 100 m. (especially in shots on epiphyses), consequent at the end of the trajectory, which is of practical importance. Since the German experiments terminate with a velocity of 170 m., they naturally find arrest more rarely than Kocher. (See Table XI.)

The explanation of the explosive effects by oscillating motion of the bullet on striking, while plausible, is rather set aside by Kocher's experiments on lead, rosin and soap, which tend to prove a simple transmission of energy.

The results on the skull are generally identical. The fact that a filled skull, in the experiments of the Germans, with reduced charge

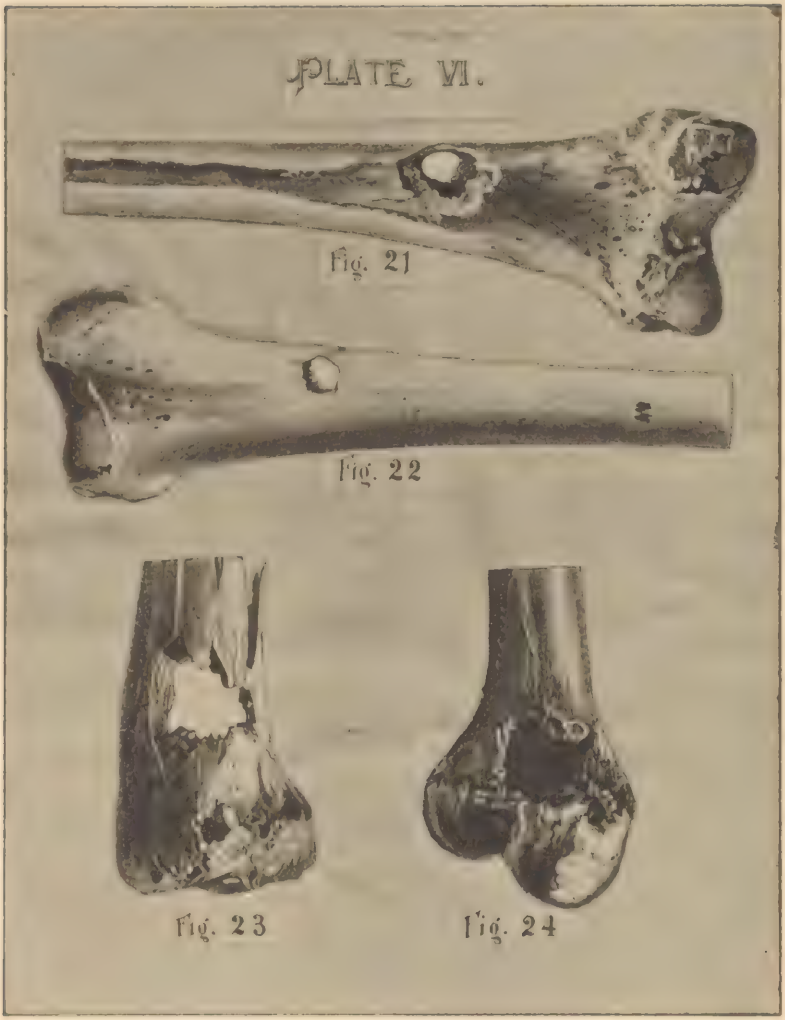
PLATE VI.
Fig. 21
Fig. 22
Fig. 23
Fig. 24

at 700 m. presented a simple perforation, need not necessarily vitiate Kocher's experiments, since he obtained with the same velocity (300 m.) an entrance perforation with extensive radial fissuring, while the exit showed marked explosive comminution.

While Kocher finds simple perforation as a rule in dry epiphyses, and frequently in dry diaphyses, the Germans find no difference. The results in experiments on the extremities are about identical as far as the moist bones are concerned, which practically is of principal value, but here also the zone of least velocity is absent in the German experiments, Kocher reporting fissures in the diaphyses, and sometimes arrest in both epiphyses and diaphyses. It is eviden from both series of observations that the more humane effect of the modern small calibre rifle with high velocity is unfortunately a myth, and that, with the possible exception of slighter muscle injuries, we will have in the future to encounter more severe injuries to the bones, and on account of its greater range a greater number of injuries. If there is a range at which the lesions are relatively less severe, it will be found at a range of between 700 and 1100 metres.

Note.—I have selected for photogravure a few of the most striking pictures from a series entrusted to me by Prof. Kocher. This series represents the illustrations which are to accompany his report on his experiments, of which he gave an extract, with exhibits of the preparations, at one of the general sessions of the International Congress at Rome.

An atlas of photogravures was distributed by the members of the German Commission, representing results of their firings, with full description. The copy in my possession will with pleasure be loaned to any member interested in these experiments, but I believe that copies can be obtained from the German War Department on application.

Explanatory Text for Plates.

Experiments on glass plates 3 m.m. thick, showing effects at the several velocities, irrespective of quality of bullet.

Plate I.—One-fourth natural size.

Fig. 1. Copper jacket. Cal. 7, 5. Vel. 100 m.
Fig. 2. Copper jacket. Cal. 7, 5. Vel. 250 m.
Fig. 3. Hard lead, steel point. Cal. 7, 5. Vel. 595 m.
Fig. 4. Round ball of wax. Vel. 425 m.
Fig. 5. Round ball of lead. Vel. 425 m.
Fig. 6. Round ball of iron. Vel. 425 m.

Plate II.—One-third natural size.

Fig. 7. Tin bucket filled with marbles. Steel jacket, 7, 5. Vel. 595 m.

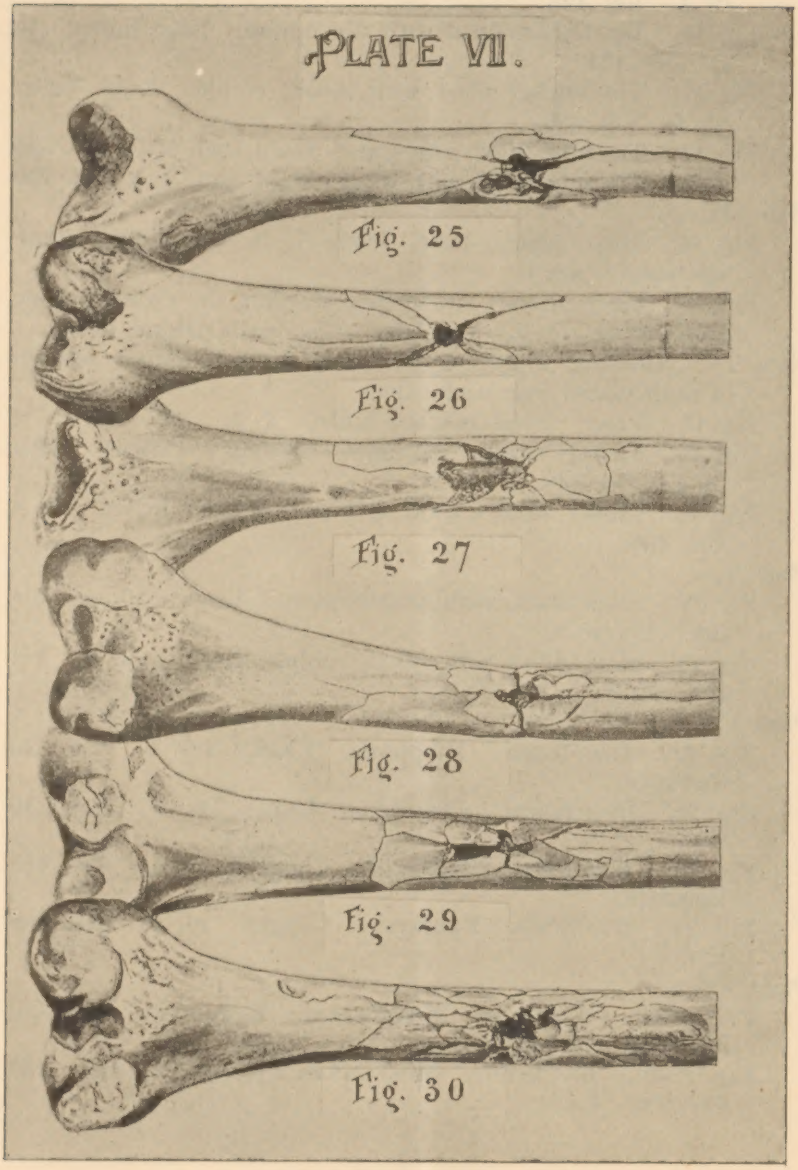
PLATE VII.
Fig. 25
Fig. 26
Fig. 27
Fig. 28
Fig. 29
Fig. 30

Fig. 8. Lead plate. Steel pointed bullet, 7, 5. Vel. 600.

Fig. 9. Tin bucket filled with dry horseflesh. Lead bullet. 10, 4. Vel. 425.

Fig. 10. Tin bucket filled with dry cotton. Lead bullet. 10, 4. Vel. 425.

Fig. 11. Tin bucket filled with moist cotton. Lead bullet. 10, 4. Vel. 425.

Fig. 12. Tin tube filled with water. Hard lead. 7, 5. Vel. 595.

Fig. 13. Tin tube filled with water. Hard lead. 7, 5. Vel. 150.

Plate III.—

Fig. 14. Soap plate. Hard lead. 7, 5. Vel. 595. (One-half natural size.)

Fig. 15. Piece of clay, cut in two, showing the channel made. Steel jacket. 7, 5. Vel. 500. (One-tenth natural size.)

Plate IV. Showing injury to liver and to two empty sections of skull placed over each other.

Fig. 16. Liver. Steel pointed bullet. 7, 5. Vel. 590.

Fig. 17. Empty skull. Entrance opening. Copper bullet. 10, 4. Vel. 400.

Fig. 18. Empty skull. Exit opening. Copper bullet. 10, 4. Vel. 400.

Plate V.—

Fig. 19. Skull filled with potato pulp. Lead. 10, 4. Vel. 435. Entrance.

Fig. 20. Skull filled with potato pulp. Lead. 10, 4. Vel. 435. Exit.

Plate VI.—

Fig 21. *Dry* femur. Diaphysis. Lead. 10, 4. Vel. 50. Entrance.

Fig. 22. *Dry* femur. Diaphysis. Lead. 10, 4. Vel. 50. Exit.

Fig. 23. *Wet* Tibia. Epiphysis. Copper. 10, 4. Vel. 435. Entrance.

Fig. 24. *Wet* Tibia. Epiphysis. Copper. 10, 4. Vel. 435. Exit.

Plate VII.—

Fig. 25-27. *Wet* femur. Steel jacket. 7, 5. Vel. resp. 150. 300, 590. Entrance.

Fig. 28-30. *Wet* femur. Steel jacket. 7, 5. Vel. resp. 150, 300, 590. Exit.